# SUSY searches: where Tevatron may help LHC analyses

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# Overview

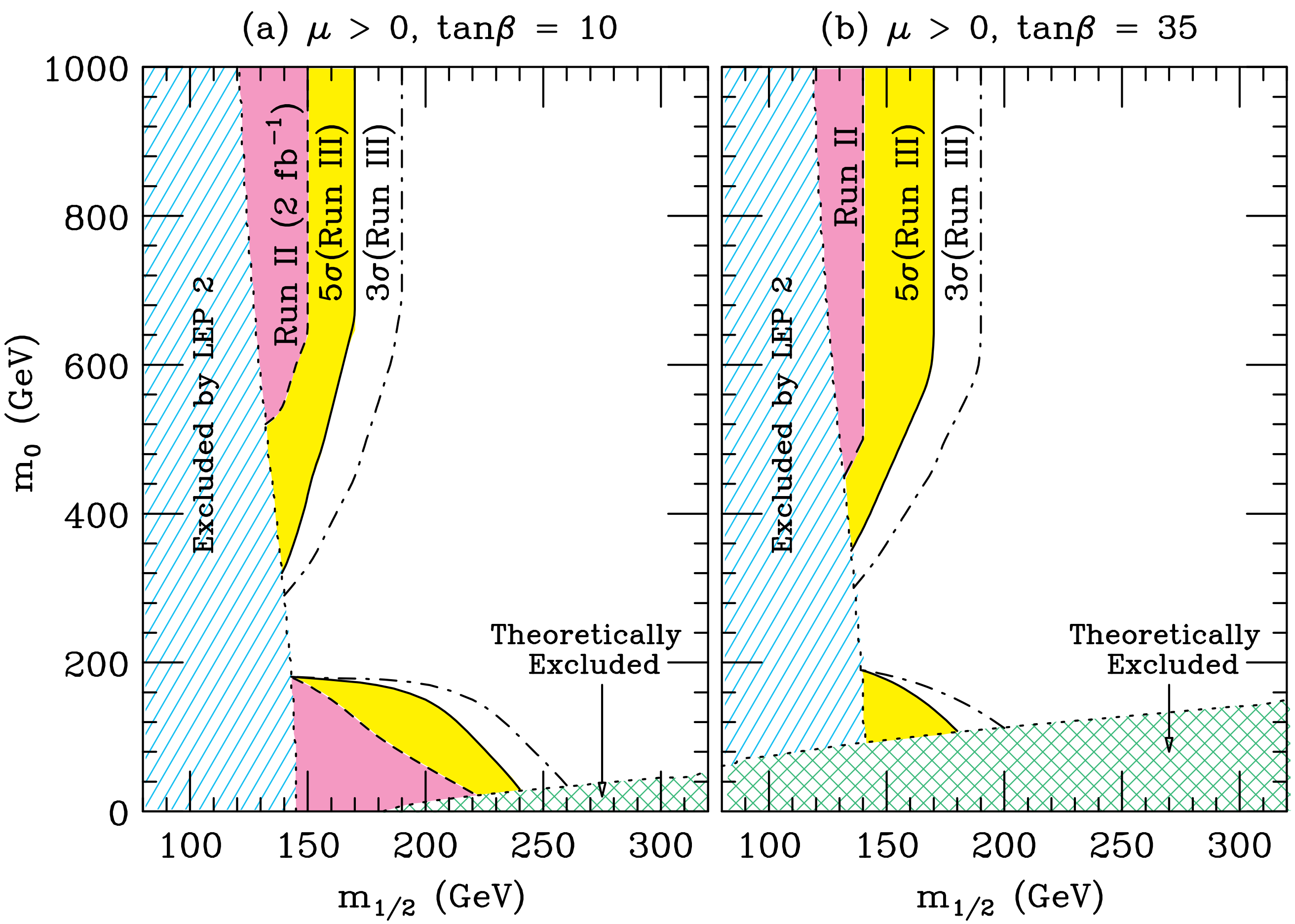
- Classic SUSY search at Tevatron / LHC
- Light stop
- Light non-standard Higgs
- Hint for large $\tan\beta$ from $B \to \mu\mu$

# Classic SUSY search - Tevatron

- $p\bar{p} \to \tilde{g}\tilde{g}, \tilde{q}\bar{\tilde{q}}$ production with $\tilde{g} \to q\tilde{q}$, $\tilde{q} \to q\tilde{\chi}^0, q'\tilde{\chi}^\pm$
  - jets $+ \not{E}_T$ signature
  - reach in $m_{\tilde{g}}$ up to $\sim 400$ GeV $(m_{1/2} \sim 150)$ with 2 fb$^{-1}$
- $p\bar{p} \to \tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production $\rightsquigarrow$ trilepton signature
  - $\tilde{\chi}_1^\pm \to \tilde{l}^\pm \nu, W^\pm \tilde{\chi}_1^0 \to l^\pm \nu \not{E}_T$
  - $\tilde{\chi}_2^0 \to \tilde{l}^\pm l^\mp, Z^0 \tilde{\chi}_1^0 \to l^\pm l^\mp \not{E}_T$
  - reach in $m_{\tilde{\chi}_1^\pm}$ up to $\sim 200$ GeV with 2 fb$^{-1}$
- Specialized searches for GMSB, AMSB, RPV, ...., cases
- Limits are in general very model dependent;
  non-obs of $3l$ signal does not lead to lower limit on $m_{\tilde{\chi}_1^\pm}$!

# Tevatron reach in mSUGRA

## trilepton signature

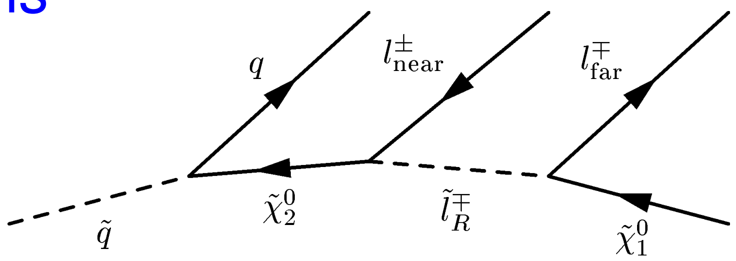



[SUGRA WG for RUN II, hep-ph/0003154]

# Classic SUSY search - LHC

- Huge $pp \to \tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{g}\tilde{q}$ cross section
  $\to$ jets $+ \not{E}_T$ covers squark and gluino masses up to 2–3 TeV.

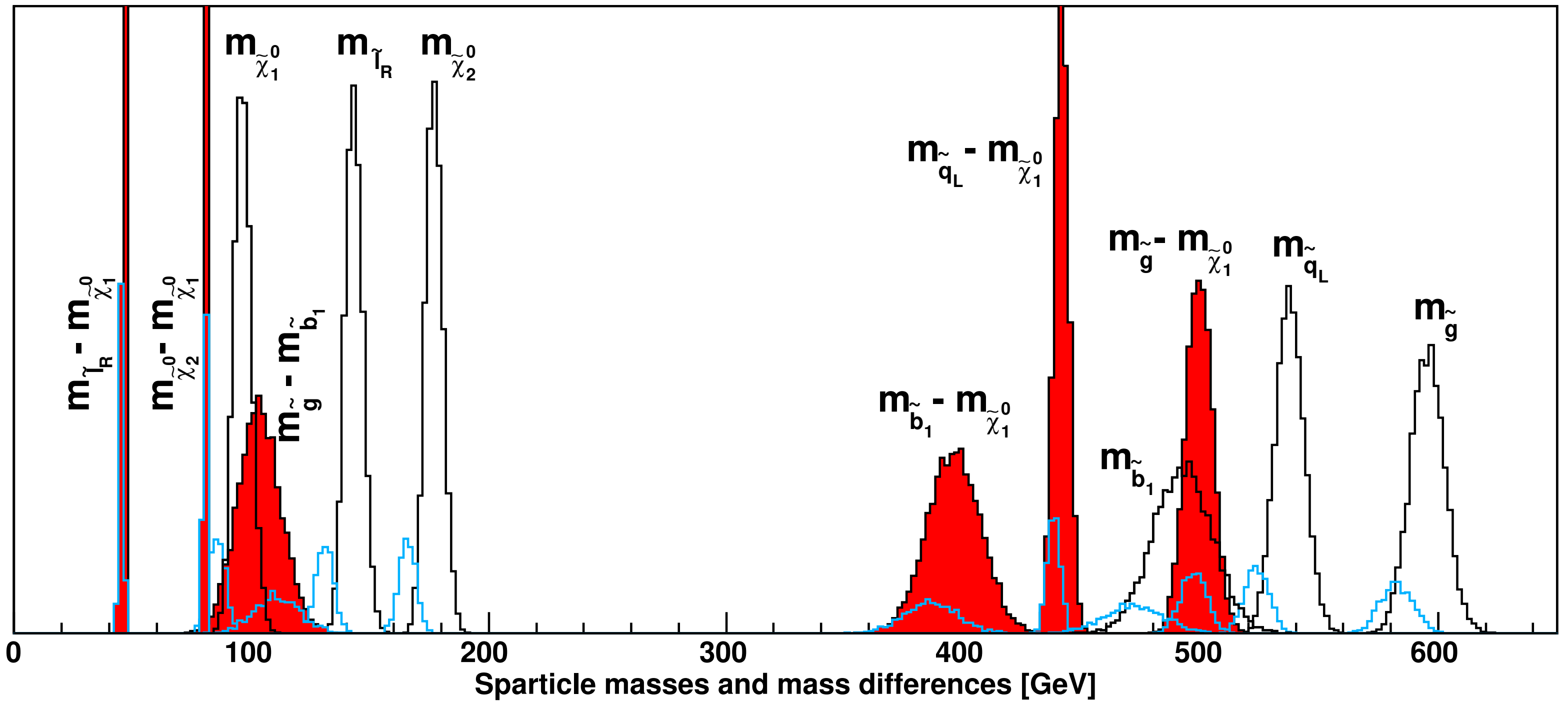
- Long decay chains




  - Search for 2l SFOS, 2l SS, 1l inclusive signatures
  - Mass determinations through kinematic endpoints
    (c.f. talk by Dirk Zerwas)
  - $\tilde{b} \to b\tilde{\chi}^0_{1,2}$ is OK but no successful analysis yet for $\tilde{t}$
  - Direct production of $\tilde{\chi}$'s and $\tilde{l}$'s has (too) low rate
  - Large $\tan\beta$: $l \to \tau$, challenging!

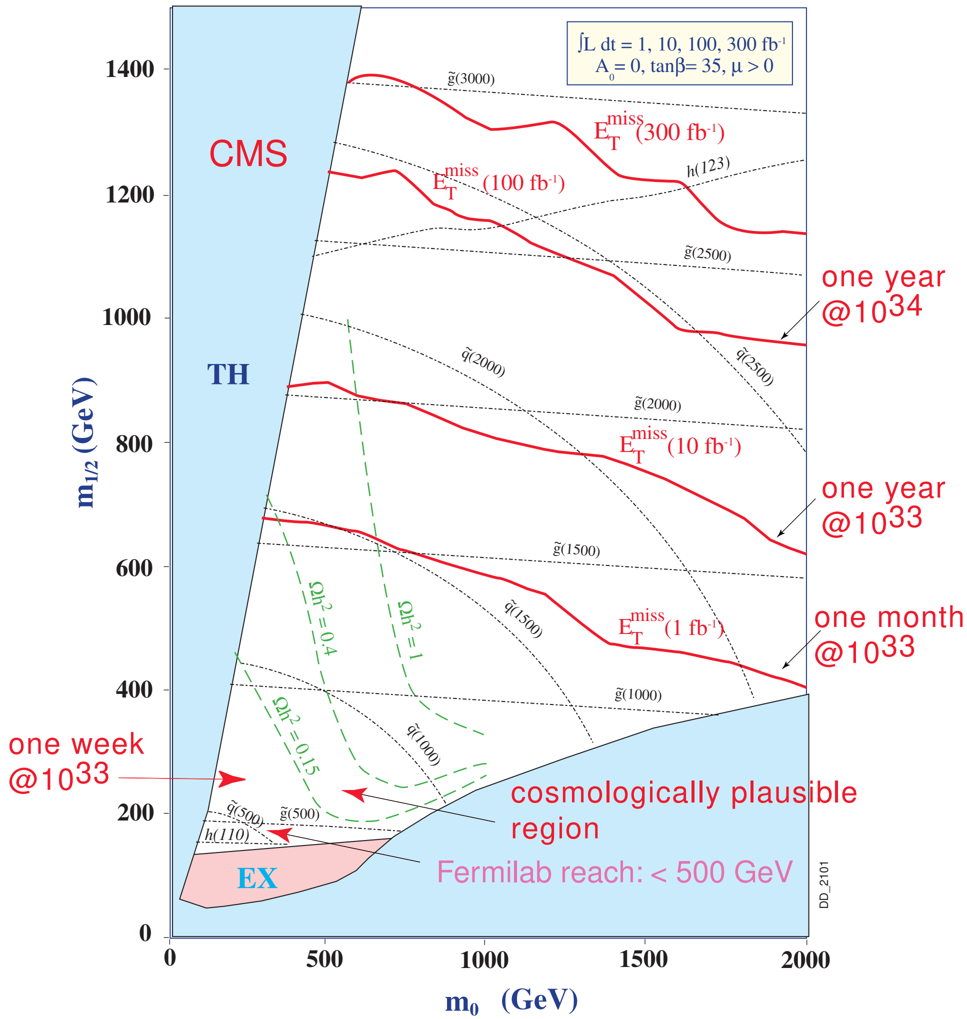
# LHC expectation for SPS1a

$$m_0 = 100,\ m_{1/2} = 250,\ A_0 = -100,\ \tan\beta = 10,\ \mu > 0$$




[Gjelsten, Miller, Osland, hep-ph/0501033]

# LHC reach in mSUGRA

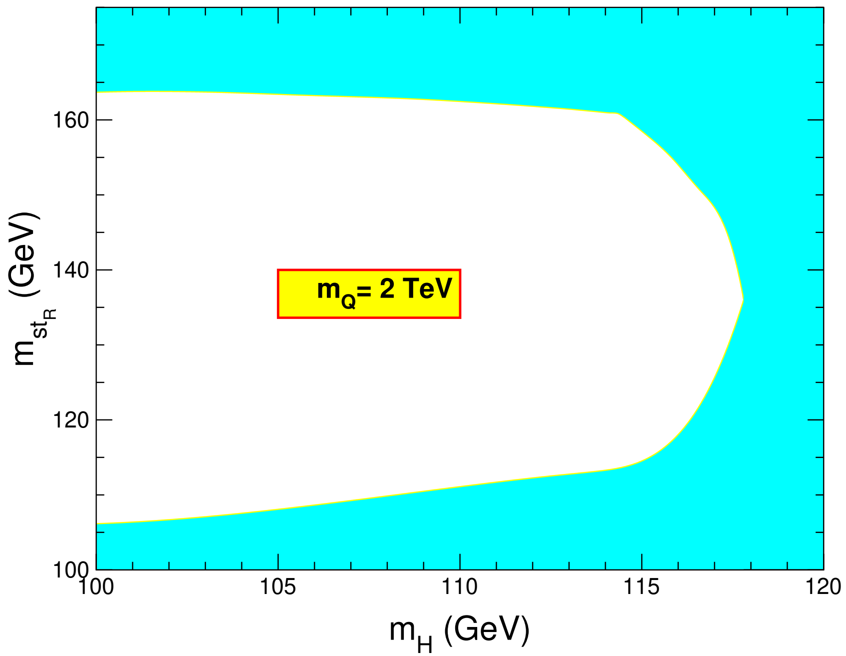



Catania 18

[CMS, Abdullin et al, hep-ph/9806366]

# Light Stop

Motivation: sufficiently strong first order phase transition to preserve generated baryon asymmetry




$m_h \lesssim 120$ GeV

$m_{\tilde{t}_1} \lesssim 165$ GeV

moderate $\tan\beta \sim 5$

[Carena, Quiros, Wagner, 1998]

NB: Right $\Omega h^2$ from $\tilde{\chi}_1^0 \tilde{t}_1$ coannihilation: $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \sim 30$ GeV. Otherwise other contributions from e.g. light sleptons needed.

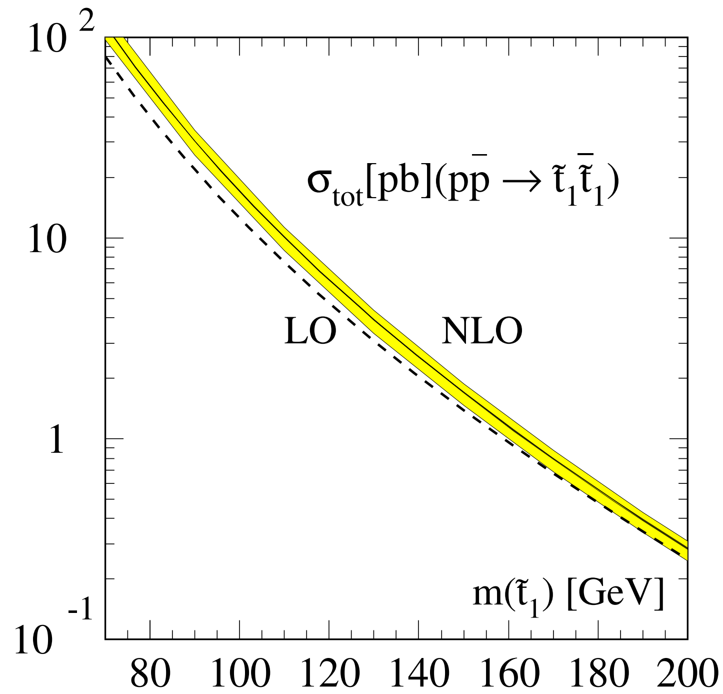
# $\tilde{t}_1$ rates and signatures

- Large rate of $p\bar{p} \to \tilde{t}_1\bar{\tilde{t}}_1$

- Decay $\tilde{t}_1 \to c\tilde{\chi}_1^0 \rightsquigarrow 2j + \not{E}_T$

- Other modes: $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm},\ bW\tilde{\chi}_1^0,\ bl\tilde{\nu}$

- If gluino mass $\sim$300–400 GeV:
  $p\bar{p} \to \tilde{g}\tilde{g} \to tt\ \tilde{t}_1\tilde{t}_1$
  ca. 50% of SUSY cross section



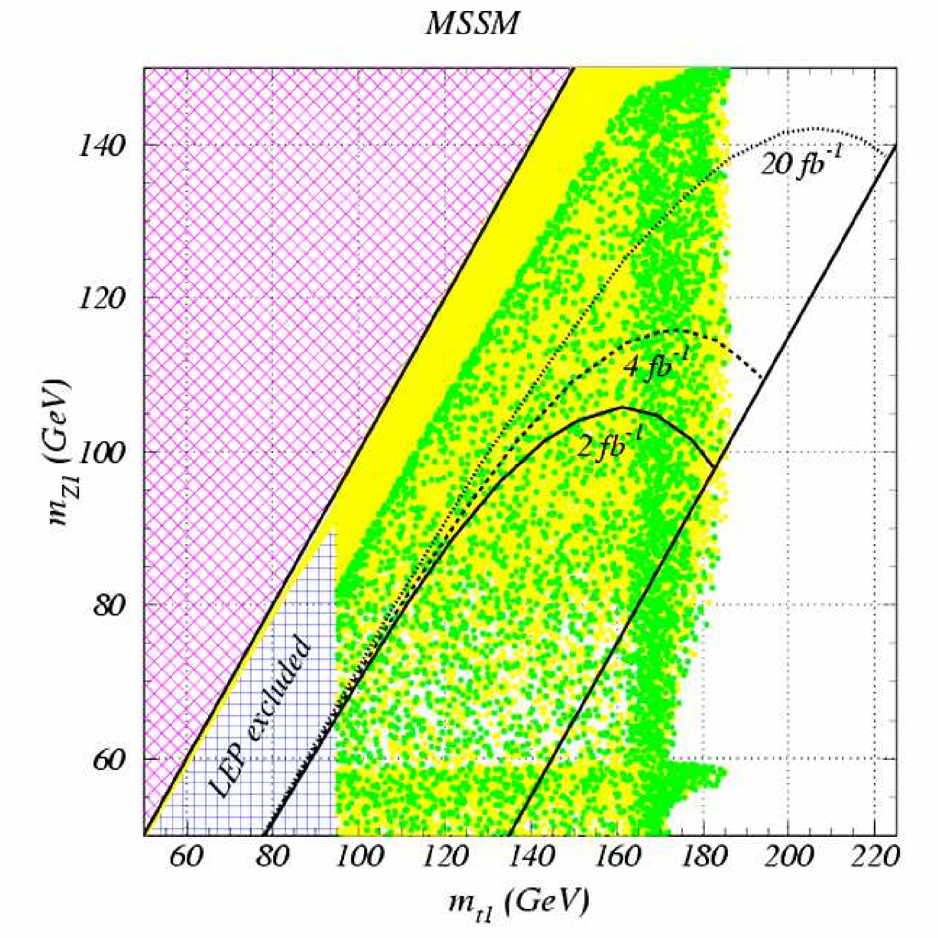

[Plehn, Spira]

- Possible discovery channel at Tevatron

- At LHC: $pp \to \tilde{g}\tilde{g} \to tt\ \tilde{t}_1\tilde{t}_1$, $pp \to \tilde{g}\tilde{b} \to tW\tilde{t}_1\tilde{t}_1$, ....

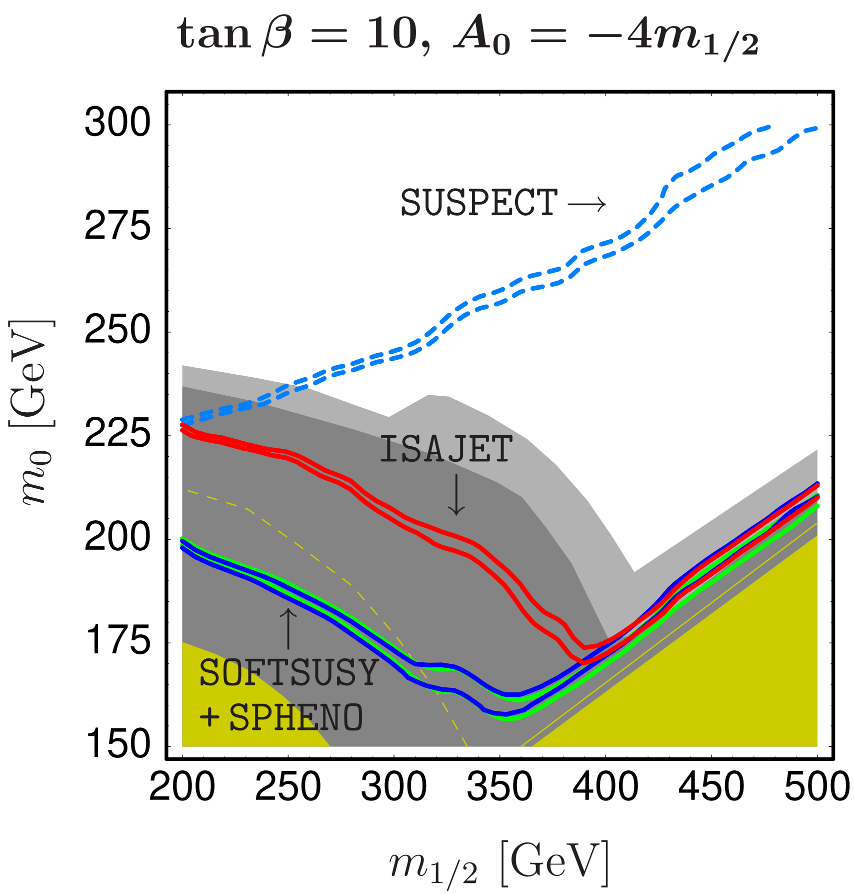
VERY difficult if stop is light

# Tevatron reach for $\tilde{t}_1 \to c\tilde{\chi}_1^0$




[Balazs, Carena, Wagner, hep-ph/0403224]

# Differences in spectrum codes




WMAP allowed regions with a light stop in mSUGRA

[Belanger, SK, Pukhov, hep-ph/0502079]

| | ISAJET 7.71 | SOFTSUSY 1.9 | SPHENO 2.2.2 | SUSPECT 2.3 |
|---|---|---|---|---|
| $\tilde{\chi}_1^0$ | 140.8 | 143.2 | 142.5 | 143.0 |
| $\tilde{\tau}_1$ | 156.1 | 157.8 | 158.9 | 160.7 |
| $\tilde{t}_1$ | 153.7 | 173.3 | 172.7 | 109.7 |
| $h^0$ | 108.8 | 114.1 | 115.6 | 108.3 |
| $m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0}$ | 15.3 | 14.6 | 16.4 | 17.7 |
| $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ | 12.9 | 30.1 | 30.2 | $-33.3$ |
| $\Omega h^2$ | 0.004 | 0.116 | 0.120 | – |

$m_0 = 161$ GeV, $m_{1/2} = 350$ GeV, $A_0 = -1400$ GeV,
$\tan\beta = 10$, $\mu > 0$, $m_t = 175$ GeV

# Light non-standard Higgs

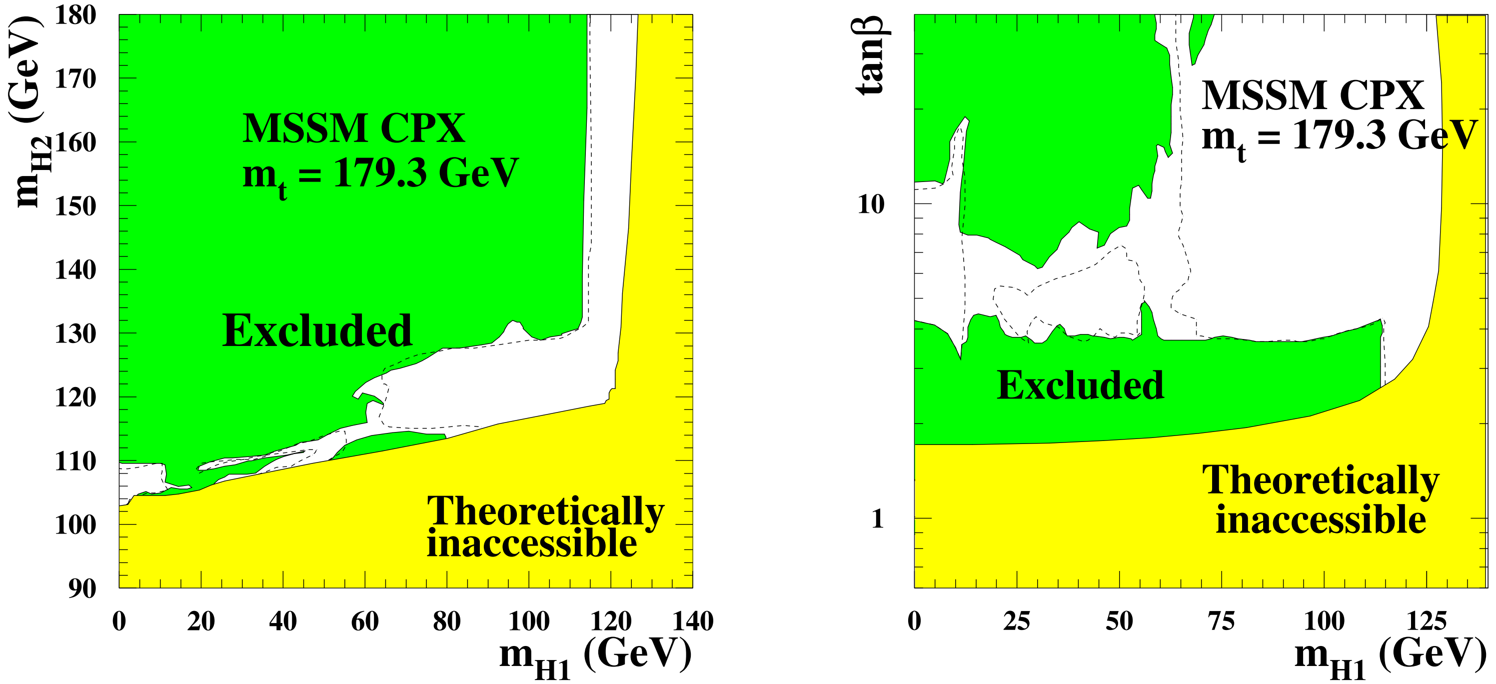
- In scenarios beyond the MSSM, the h couplings to Z can be suppressed; LEP limit of $m_h > 114$ GeV no longer applies
- Examples:
  - MSSM with CP-violating phases
  - NMSSM with light pseudoscalars (low fine tuning)
- Consequence: $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \phi_i \to \tilde{\chi}_1^0 b\bar{b}$ $(\tau\tau)$ or even $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \phi_j \to \tilde{\chi}_1^0 \phi_1 \phi_1 \to \tilde{\chi}_1^0\, 4b$ $(4\tau)$ can have large BR
  - ★ impacts Tevatron and LHC analyses of SUSY decay chains
- Need to cover light (CPV) Higgs, light pseudoscalars, Higgs-to-Higgs decays: $\phi_2 \to \phi_1 \phi_1 \to 4b$ or $4\tau$
- Opportunity for searches at the Tevatron?

(c.f. CPNSH workshop)

# LEP limit on CPV MSSM Higgs

MSSM CP phases $\rightsquigarrow$ mixing of $(h^0, H^0, A^0) \to (h_1, h_2, h_3)$

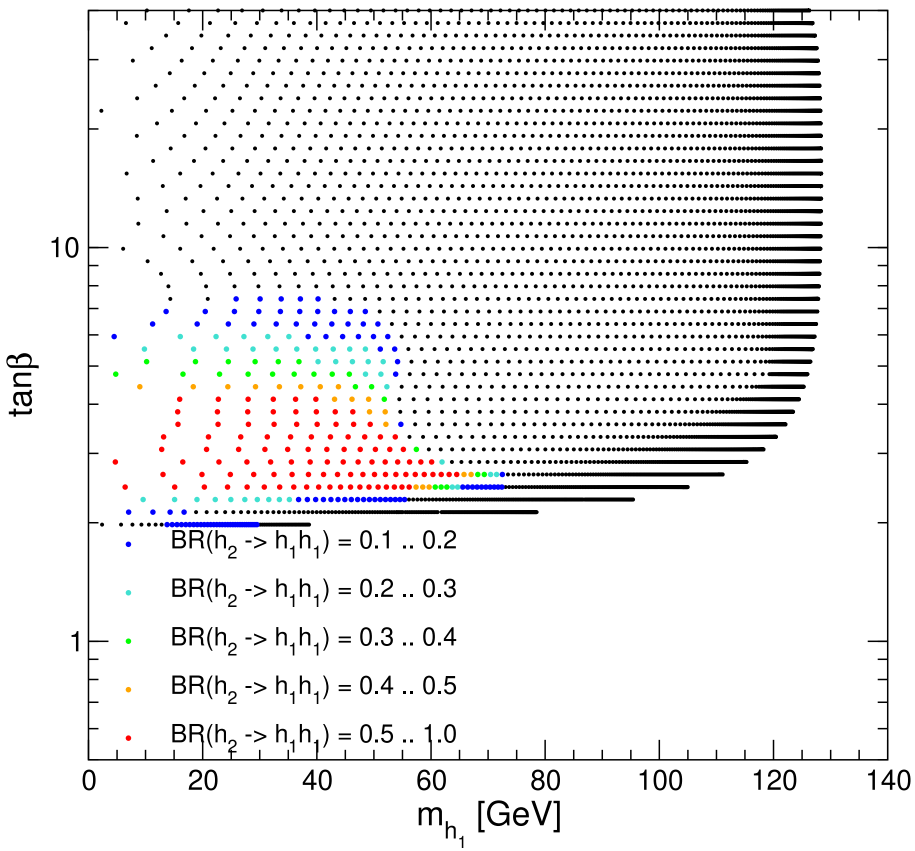
$$O_{ij}^2 \sim \frac{m_t^4}{v^2} \frac{\mathrm{Im}(\mu A)}{32\pi^2 M_{SUSY}^2}$$




[LHWG-Note-2004-01]

CPV can drastically change Higgs/SUSY production rates and BR's

# $\mathbf{BR}(h_2 \to h_1 h_1)$ in CPV MSSM



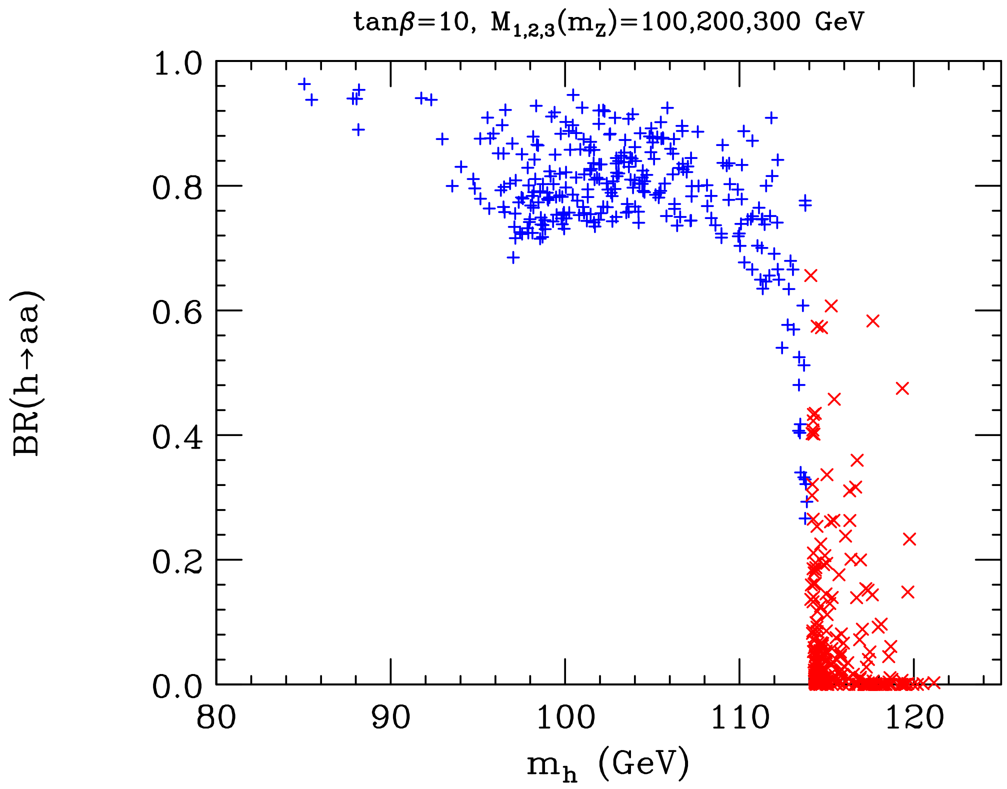

[Sven Heinemeier]

$\longrightarrow$ Sven's talk in the afternoon

# $\mathrm{BR}(h \to aa)$ in NMSSM

$$\mu \hat{H}_1 \hat{H}_2 \to \lambda \hat{S} \hat{H}_1 \hat{H}_2 + \frac{\kappa}{3} \hat{S}^3$$

3 neutral scalar, 2 pseudoscalar, 2 charged Higgs bosons




see discussion in [Ellwanger, Gunion, Hugonie, hep-ph/0503203]

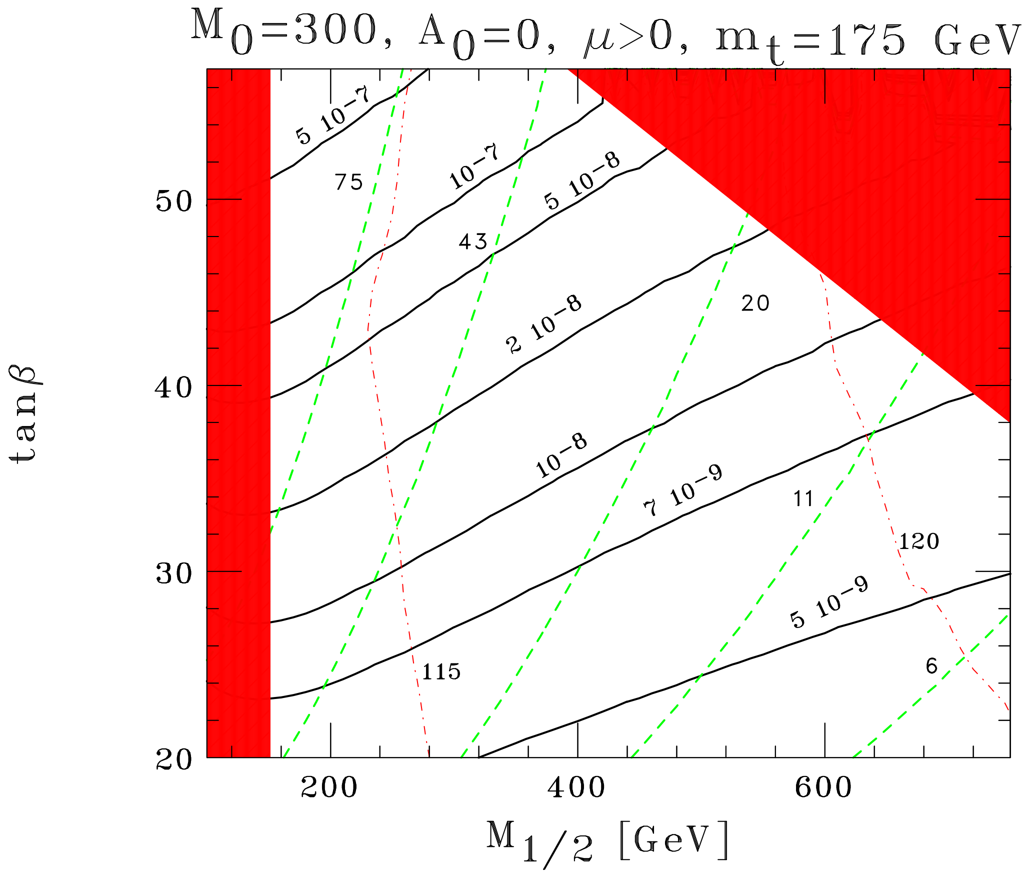
# BR($B_s \to \mu\mu$)

- Present bound: BR($B_s \to \mu^+\mu^-$) $< 5.8 \times 10^{-7}$
- SM prediction: BR($B_s \to \mu^+\mu^-$) $= (3.4 \pm 0.5) \times 10^{-9}$
- In SUSY, the $B \to \mu\mu$ branching ratio grows like $\tan^6\beta$, orders of magnitude enhancement, BR$\sim 10^{-7}$ for $\tan\beta = 50$
- If deviation from SM prediction observed at the Tevatron:

  $\star$ large $\tan\beta$ interpretation in SUSY $\star$

- Consequence: expect many $\tau$'s in SUSY decay chains at Tevatron and LHC $\longrightarrow$ optimize $\tau$ identification, want good $\tau$ energy and polarization measurements, etc.

# $\mathbf{BR}(B_s \to \mu\mu)$



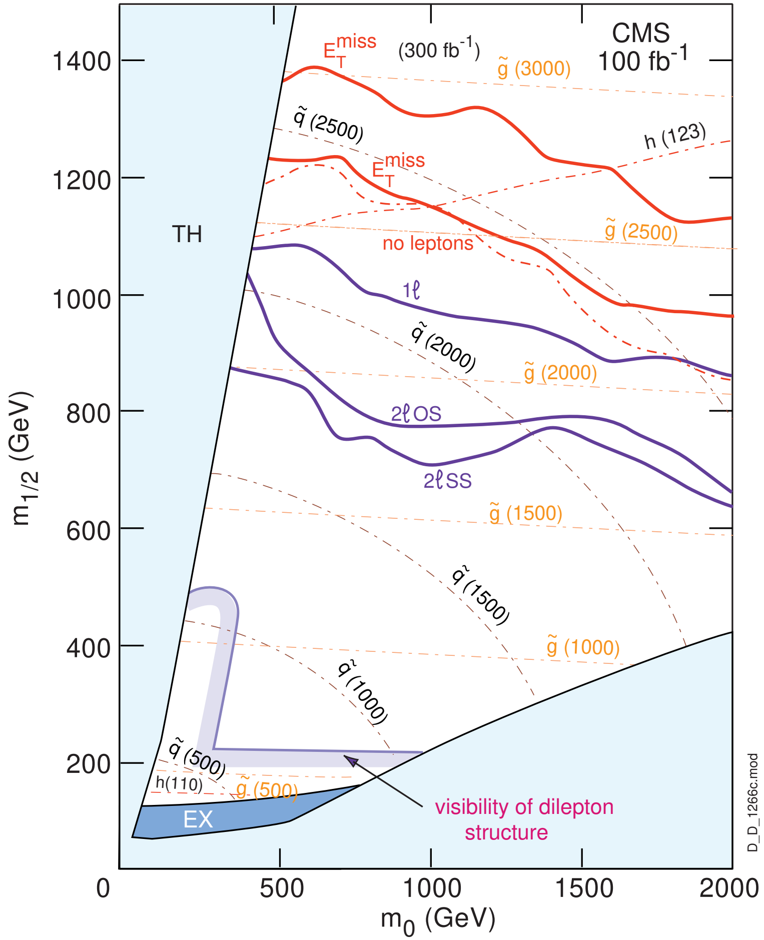

[Dedes, Dreiner, Nierste, hep-ph/0108037]

# Summary

- Light stop, $m_{\tilde{t}_1} < m_t$, motivated by BAU
  - Some of the cosmologically interesting region can be covered by Tevatron search
  - Neutralino-stop coannihilation region however not covered ($\Delta m \sim 30$ GeV)
- Light non-standard Higgs, $m_\phi \ll 114$ GeV
  - Can impact SUSY decay chains by $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 \phi_i$
  - Opportunity for Tevatron Higgs searches; Higgs-to-Higgs decays however not yet studied
- Deviation from SM in $B \to \mu\mu$: SUSY interpretation would suggest large $\tan\beta \rightsquigarrow \tau$'s in SUSY decay chains
- In addition: experience with real data, trigger, particle identification, etc. ...... G. Polesello's talk at TEV4LHC in Feb05

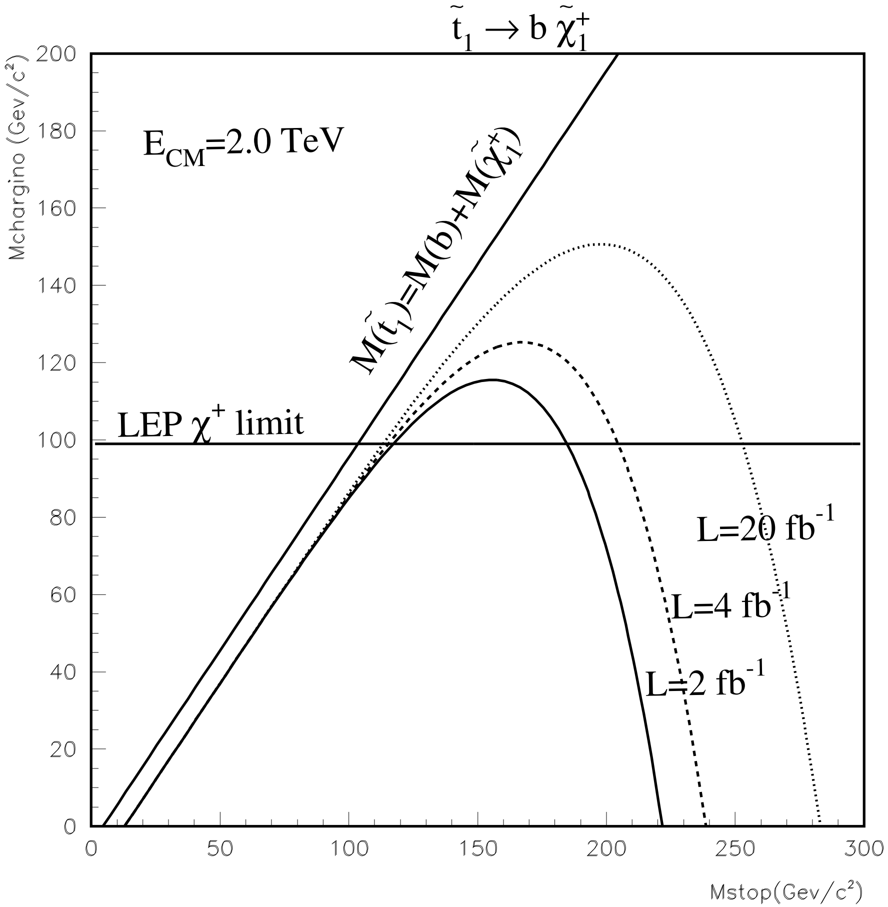
# backup

# LHC reach in mSURGA



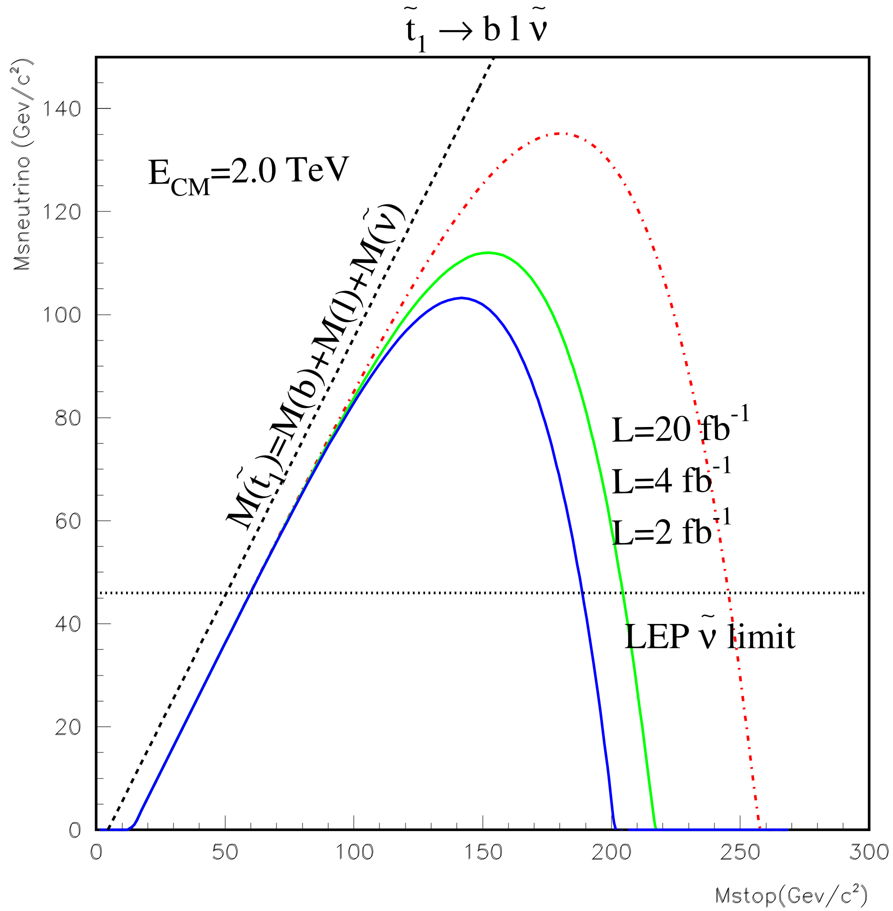

[CMS, Abdullin et al, hep-ph/9806366]

# Tevatron reach for $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm}$




[SUGRA WG for RUN II, hep-ph/0003154]

# Tevatron reach for $\tilde{t}_1 \to b l \tilde{\nu}$




[SUGRA WG for RUN II, hep-ph/0003154]